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PIEZOELECTRIC ACTUATOR

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[0001] ~~Prior Art~~ Background Of The Invention

Field Of the Invention

[0002] The invention relates to a piezoelectric actuator, for instance for actuating a mechanical component such as a valve or the like, in accordance with the generic characteristics of the preamble to the main claim.

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Description of the Prior Art

[0003] It is widely known that by utilizing the so-called piezoelectric effect, a piezoelectric element can be constructed from a material with a suitable crystalline structure. When an external electrical voltage is applied, a mechanical reaction of the piezoelectric element takes place, which depending on the crystalline structure and the regions where the electrical voltage is applied causes a compression or tension in a predeterminable direction.

[0004] The aforementioned piezoelectric actuators are often used in the positioning of valves. Among other factors, it must be considered here that their stroke capacity for actuating a valve tappet, for instance, is relative slight. On the other hand, the different thermal expansion of the ceramic comprising the piezoelectric element as opposed to the housing causes problems; the piezoelectric element has only very slight temperature expansion, and the housing, which as a rule is of metal, has a positive temperature expansion, which

can cause a drift in the position of the valve tappet without any triggering of the piezoelectric element.

[0005] In the conventional way, until now it was possible to reduce such problematic effects only by employing very expensive materials, such as Invar, that have a negative temperature expansion. Another way was to connect a material of high temperature expansion in series with the piezoelectric element, but that reduces the rigidity of the system and hence the ak force.

Summary Of The Invention

[0006] Advantages of the Invention

[0007] The piezoelectric actuator described at the outset, which can be used for instance to actuate a mechanical component, advantageously has a piezoelectric element, parallel to which, according to the invention, a compensating element is disposed. It is especially advantageous that the piezoelectric element and the compensating element have essentially the same coefficients of temperature expansion, so that given a suitable mechanical mounting of the two elements, the temperature-caused expansions in the piezoelectric element and the compensating element cancel one another out in the effective direction in such a way that an actuating element solidly connected to a pressure plate of the piezoelectric element remains in its position. It is thus possible in a simple way to use a metal housing, for instance of steel, for the piezoelectric actuator as before and to brace the

piezoelectric element in the housing in such a way that the compensating element is always solidly connected to the piezoelectric element for the sake of temperature compensation.

[0008] In an advantageous embodiment, the piezoelectric element in its effective direction rests with one end against a fixation edge of a housing via a spring and with its other end on another fixation edge of the housing via a pressure plate and a prestressing spring. A spring plate is also present, which is disposed between the piezoelectric element and the spring. According to the invention, the compensating element is additionally disposed on this spring plate and with its other end abuts the housing firmly and moreover is parallel to the piezoelectric element.

[0009] In a first refined embodiment, the piezoelectric element comprises a multilayered structure of transversely disposed ceramic piezoelectric layers, which lengthen in the effective direction when an external electrical voltage is suitably applied. The compensating element is likewise constructed of ceramic, with the same coefficients of temperature expansion as the layers of piezoceramic, but this ceramic has no piezoelectric effect. A possible differential expansion between the housing of the piezoelectric actuator and the piezoelectric element that would cause a deflection of the actuating element is thus compensated for via the spring

that is located between the spring plate and the fixation edge of the housing.

[0010] In a second embodiment, the piezoelectric element likewise comprises a multilayered structure of transversely disposed ceramic piezoelectric layers, which lengthen in the effective direction when an external electrical voltage is applied. The compensating element here is constructed of longitudinally disposed piezoelectric layers, which shorten in the effective direction when an external electrical voltage is applied. Once again, as mentioned above, a possible differential expansion between the piezoelectric actuator housing and the piezoelectric element can be compensated for by means of the same temperature coefficient for the piezoelectric element and the compensating element and by means of the compensation via the aforementioned spring. However, in addition, this embodiment of the invention also makes it possible to lengthen the stroke of the piezoelectric actuator, so that other additional provisions such as a hydraulic coupling can be dispensed with. Because of the lengthened stroke, an otherwise possibly necessary stroke boost can also be dispensed with.

[0011] In advantageous refinements of the invention, the piezoelectric element and the compensating element can be constructed in bar form, with a round or rectangular cross section. It is also possible here for the piezoelectric element and the compensating element to comprise hollow

cylinders, which are disposed about the axis of the actuating element, to make an overall cylindrical design of the piezoelectric actuator easier.

[0012] In a first application of the piezoelectric actuator of the invention, the end of piezoelectric element by which it rests on the pressure plate, and thus exerts a force on the actuating element, can advantageously be disposed on the far side of the piezoelectric actuator in terms of the effective direction. In that case, the useful force of the piezoelectric actuator is a tensile force.

[0013] In a second advantageous application, the end of piezoelectric element by which it rests on the pressure plate, is disposed on the side of the piezoelectric actuator located in the effective direction. In this second case, the useful force of the piezoelectric actuator is a compressive force.

[0014] These and other characteristics of preferred refinements of the invention will become apparent from the claims and the description and the drawings; the individual characteristics, each alone or a plurality of them in the form of subsidiary combinations, can be realized in the embodiment of the invention and in other fields and can represent both advantageous and intrinsically patentable embodiments for which patent protection is here claimed.

[0015] ~~Drawing~~ Brief Description of The Drawings

[0016] Exemplary embodiments of the piezoelectric actuator of the invention with a narrow design, for instance for positioning a valve, will be explained in conjunction with the drawing. Shown are:

[0017] Fig. 1, a section through a piezoelectric actuator, acting with a tensile force, with a compensating element of ceramic;

[0018] Fig. 2, a section taken along the line A-A of Fig. 1, with a barlike design of the piezoelectric element of Fig. 1 and showing a first possibility for lead bonding;

[0019] Fig. 3, a section corresponding Fig. 2, with a second possibility for lead bonding;

[0020] Fig. 4, a section taken along the line A-A of Fig. 1, with a hollow-cylindrical design of the piezoelectric element of Fig. 1;

[0021] Fig. 5, a section through a piezoelectric actuator, acting with a compressive force, with a compensating element of piezoceramic layers;

[0022] Fig. 6, a section taken along the line A-A of Fig. 5 with a barlike design of the piezoelectric elements of Fig. 5 and showing a first possibility for lead bonding;

[0023] Fig. 7, a section corresponding to Fig. 6, showing a second possibility for lead bonding; and

[0024] Fig. 8, a section taken along the line A-A of Fig. 5, with a hollow-cylindrical design of the piezoelectric elements of Fig. 5.

Description Of The Preferred Embodiments

[0025] Description of the ~~Exemplary~~ Embodiments

[0026] In Fig. 1, a piezoelectric actuator 1 is shown, which has a piezoelectric element 2 that in a manner known per se is constructed of piezoelectric sheets of a quartz material of a suitable crystalline structure, so that by utilizing the so-called piezoelectric effect, when an external electrical voltage is applied to electrodes, not shown in this drawing, a mechanical reaction of the piezoelectric actuator 1 ensues.

[0027] In the piezoelectric actuator 1 of Fig. 1, the piezoelectric element 2 is of ceramic, and a compensating element 3, also of ceramic but without a piezoelectric effect, is pressed by a spring 4 via a spring plate 5 against a fixation edge of the housing 6. The elements 2 and 3 have the same coefficients of temperature expansion. The piezoelectric element 2 is prestressed from above by the prestressing spring 7 and a pressure plate 8, and the piezoelectric element 2 is constructed with transversely stacked layers in such a way that it lengthens when an electrical voltage is applied. The pressure plate 8 is solidly connected to a tie rod 9, which

represents the actuating element, for instance for a valve tappet.

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[0028] The prestressing force F_7 of the spring 7 must be substantially less than the prestressing force F_4 of the spring 4, so that for the maximum useful force F_{useful}, in this case in the form a tensile force, of the piezoelectric actuator 1, the following equation applies:

$$F_{useful} = F_4 - F_7$$

[0029] The stiffnesses of the springs 4 and 7 should be as slight as possible. Since the temperature expansion of the piezoelectric element 2 is the same as that of the compensating element 3, any possible differential expansion between the housing 6 and piezoelectric element 2 is compensated for via the spring 4.

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[0030] Figs. 2 and 3 each show an arrangement of barlike piezoelectric elements 2 and compensating elements 3 in a section along the line A-A in Fig. 1. The lead bondings 10, 11 of the piezoelectric elements 2 are done in the Y direction in the arrangement of Fig. 2, while lead bondings 12, 13 in Fig. 3 are done in the X direction.

[0031] In Fig. 4, an arrangement with hollow-cylindrical piezoelectric elements 2 and compensating elements 3 can be seen, again in a section along the line A-A of Fig. 1. In

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this arrangement, the lead bondings 14 and 15 of the piezoelectric elements 2 are mounted on the radial side faces of the piezoelectric element 2.

[0032] A second exemplary embodiment of the piezoelectric actuator 1 is shown in Fig. 5, in which the components that function the same are provided with the same reference numerals as for Fig. 1. In the arrangement of Fig. 5 as well, the piezoelectric element 2 is of a suitable piezoceramic; a compensating element 20, however, is also constructed like a piezoelectric element, and in a modification of the example of Fig. 1, these elements 2 and 20 are pressed by the spring 4 via the spring plate 5 against a fixation edge located at the top of the housing 6.

[0033] The piezoelectric element 2 is layered transversely, so that when an electrical voltage is applied, it lengthens, as in the first exemplary embodiment. The piezoelectric layers of the compensating element 20 are conversely longitudinally layered or stacked, so that they shorten in the effective direction when an electrical voltage is applied of the piezoelectric actuator 1.

[0034] The prestressing force of the spring 7, by way of which the lower end of the piezoelectric element 2 rests on the housing, must be substantially less than the prestressing force of the spring 4, so that for the maximum useful F_{useful}, in this case in the form of a compressive force, of the

piezoelectric actuator 1, the following equation applies:

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$$F_{useful} = F_7 - F_4$$

[0035] Once again, the stiffnesses of the springs 4 and 7 should be as slight as possible. When an electrical voltage is applied to the two elements 2 and 20, the sum of the two individual strokes of the two elements 2 and 20 is the resultant useful stroke. Since here again the temperature expansion of the two elements 2 and 20 is the same, any possible differential expansion between the housing 6 and the piezoelectric element 2 is once again compensated for via the spring 4.

[0036] In Fig. 6 and Fig. 7, an arrangement with a barlike piezoelectric element 2 and likewise barlike compensating elements 20 can be seen in a section taken along the line A-A in Fig. 5. In Fig. 6, the lead bondings of the piezoelectric element 2 are made in the X direction and those of the compensating element 20 are made in the Y direction, while in the arrangement of Fig. 7, they are made in the Y direction for the piezoelectric element 2 and in the X direction for the compensating elements 20.

[0037] In Fig. 8, an arrangement with hollow-cylindrical piezoelectric elements 2 and compensating elements 20 can be seen, again in a section taken along the line A-A of Fig. 5. The lead bondings 14 and 15 of the piezoelectric element 2 and

the compensating element 20 in this arrangement are mounted on the radial side faces.

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